HORTSCIENCE 33(4):650–651. 1998.

A Recirculating Hydroponic System for Studying Peanut (*Arachis hypogaea* L.)

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Additional index words. peanut, sphagnum moss, pegging, nutrient film technique

Abstract. **Peanut (*Arachis hypogaea* L.) plants were grown hydroponically, using continuously recirculating nutrient solution. Two culture tray designs were tested; one tray design used only nutrient solution, while the other used a sphagnum-filled pod development compartment just beneath the cover and above the nutrient solution. Both trays were fitted with slotted covers to allow developing gynophores to reach the root zone. Peanut seed yields averaged 350 g·m^{-2} dry mass, regardless of tray design, suggesting that substrate is not required for hydroponic peanut production.**

As part of NASA's investigations with bioregenerative life support systems, production studies with candidate crops are being conducted in controlled environments at the Kennedy Space Center, Fla., using continuously recirculating nutrient film technique (NFT) hydroponics. NFT is an appealing hydroponic technique because it 1) allows continuous recirculation and detailed nutrient management of the solution, 2) can be operated with relatively low water volume, and 3) is conducive to a range of species (Graves, 1983). Peanut has been selected as a candidate crop because the seeds are rich in fat and protein. However, peanut culture using NFT poses a unique challenge since the pollinated flowers develop elongated gynophores (pegs), which require a dark environment (Zamski and Ziv, 1976; Ziv and Sager, 1984) and contact with a substrate for embryo development (Lim, 1995; Zamski and Ziv, 1976). Typical NFT systems have an opaque cover over the nutrient solution (root zone) to prevent algal growth and reduce evaporation, but such a cover would hinder peg access to the root zone.

Materials and Methods

We tested two tray culture designs for peanut production in recirculating NFT. Both designs involved a slotted plastic tray cover to allow peg penetration to the dark zone. The cover (insert) was made of T-shaped plastic slats with black-on-white plastic film attached with plastic clips (notebook binders) that covered the openings between the slats (Fig. 1). The inverted plastic film "wings" eliminated light penetration into the root zone but were flexible enough to allow the pegs to enter the dark zone. The first design consisted of a culture tray for delivering nutrient solution across the roots located below the tray insert (Fig. 1), and was adapted from NFT culture trays developed for wheat studies (Prince et al., 1987). The pegs in this design were allowed to access the root zone directly and to develop in the nutrient solution. The second design consisted of the same culture tray and insert but with a shallow culture tray nested into the main tray and filled with moistened sphagnum moss. Two 37-mm-diameter holes were cut in the nested tray to support the two plants and allow the roots to reach the nutrient solution, while effectively isolating the developing pegs from the nutrient solution (Fig. 2). Sphagnum moss was used to provide a mechanical stimulus for embryo development (Zamski and Ziv, 1976). The moss was moistened at the beginning of the study with 1.0 mM $Ca(NO_3)_2$ and kept moist with deionized water for the remainder of the study in order to provide developing pegs adequate calcium (Bledsoe et al., 1949).

Peanut 'Early Bunch', a Virginia-type (spreading bunch habit), and 'Pronto', a Spanish-type (erect bunch habit), were grown from seed in a 1.8 × 2.4-m walk-in growth chamber for 16 weeks (Environmental Growth Chambers, Chagrin Falls, Ohio). Each cultivar was tested with both tray designs, allowing for two trays per cultivar and tray design (eight trays within the chamber). Twenty seeds were sown per square meter and acrylic germination covers were used to keep humidity high during germination. One week after planting, the covers were removed. At 2 weeks, stainless steel cages (60 cm tall) were installed around each tray and the sides covered with a layer of plastic screening to minimize side-lighting (Went, 1957). At this time, plants were thinned to a final density of 6.7 plants per square meter (two per tray). High-pressure sodium lamps provided 900 µmol·m^{-2}·s^{-1} photosynthetic photon flux (*PPF*) and a 12-h photoperiod. Air temperature was controlled at 26 °C day/22 °C night with relative humidity held constant at 65%. The CO_2 was maintained at 400 µmol·mol^{-1} with a computer-controlled system monitored with an infrared gas analyzer.

Nutrient solution for each treatment (four tanks) was recirculated at a flow rate of ≈1 L·min^{-1}. Water was added manually each day to maintain a constant volume (20 L). Nutrients were replenished each day using a nutri-

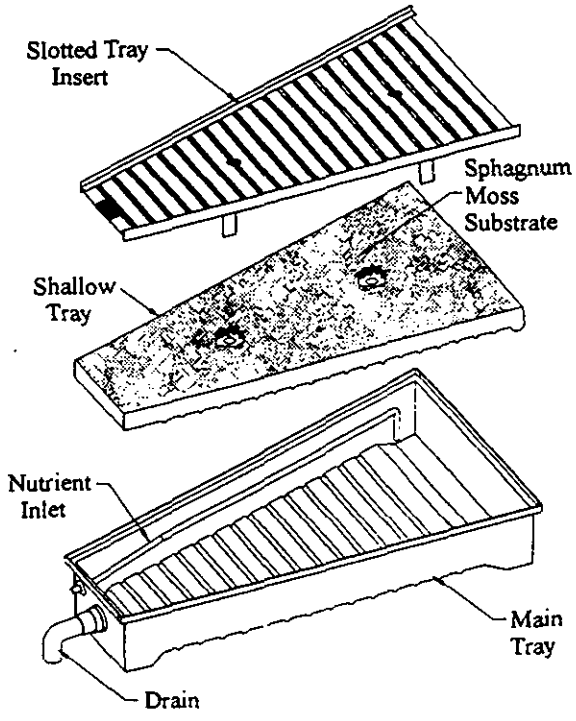

Fig. 1. Culture tray design for hydroponic peanut growth. The first design excluded the shallow tray, where pods developed directly in the root zone. The trapezoidal tray shape was incidental to the effectiveness of the total design.

Received for publication 12 Apr. 1997. Accepted for publication 17 Oct. 1997. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the National Aeronautics and Space Administration. We would like to thank Dr. David Knauft, North Carolina State Univ., for providing us with peanut seed. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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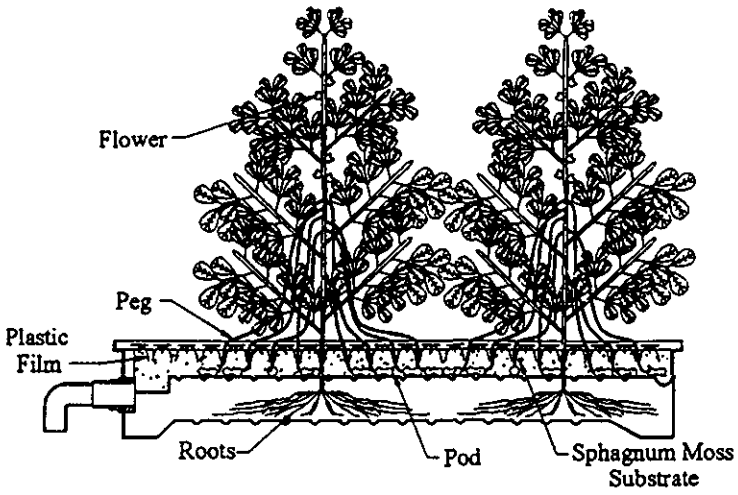

Fig. 2. Side view of peanut plants in the second culture tray design, showing pod development in the sphagnum substrate.

ent concentrate as a refill solution (Table 1), whenever solution electrical conductivity dropped below 1.2 $dS \cdot m^{-1}$ (1.2 $mmho \cdot cm^{-1}$). Solution pH was automatically maintained at 5.8 using 0.4 M HNO_3.

Results and Discussion

The two cultivars grew vigorously, with no apparent water or nutrient stress. Developing pegs were able to pass through the tray covers and reach the pod development zones in both treatments. 'Pronto' continued to develop pegs high in the canopy until the time of harvest; however, they did not elongate enough (60 cm) to reach the culture tray. The greatest seed yields (<400 $g \cdot m^{-2}$) were with 'Early Bunch' for the solution treatment and 'Pronto' for the sphagnum treatment (Table 2). Tray design did not influence seed production (data not shown). Zharare et al. (1993) found that a substrate was not necessary for peanut seed development; however, Lim (1995) found that sand, having a high bulk density, improved seed development over no substrate or media having relatively lower bulk density. Substrate influence may be cultivar-dependent but further testing is needed. Proximate nutritional analysis of our two cultivars showed the fat content was slightly less (40% vs. 50%) and the carbohydrate was slightly greater (24% vs. 20%) than that reported for field-grown plants (Duke and Atchley, 1986). This suggests that the plants were harvested before the seeds reached maturity (Kim and Hung, 1991). This is also supported by the observation that 100-count seed mass was 30% lower than typical values for these cultivars (Banks and Kirby, 1983; Norden et al., 1978).

Vegetative biomass (leaves + stems) was high for both treatments, with average dry-mass values of 2.4 and 1.9 $kg \cdot m^{-2}$ for 'Early Bunch' and 'Pronto', respectively. This contributed to low harvest indices of 11% and 14% for 'Early Bunch' and 'Pronto', respectively. Luxuriant vegetative growth has been reported for peanut grown in hydroponic systems (Lim, 1995). Peanuts generally have an indeterminate growth habit and produce more vegetative biomass when grown under low irradiance (Ketring, 1979) and/or warm temperatures (Marshall et al., 1992). Moreover, reproductive growth tends to decrease as vegetative biomass increases (Ketring, 1979). Although our incident radiation was relatively high (900 $\mu mol \cdot m^{-2} \cdot s^{-1}$), we shaded the sides of the plants to minimize border effects. In a previous study, shading prior to pegging increased vegetative growth (20%), while shading during pod fill and maturation reduced seed fill and overall yields (Hang et al., 1984).

Chen and Sung (1990) suggested that an excessive sink load (large proliferation of gynophores) can reduce overall seed fill, since depegging increased seed fill, even when carbon fixation was not limited (atmospheric CO_2 enrichment). Breeding for a determinate cultivar (limiting peg formation) may improve seed fill in controlled environments where optimal environmental conditions and ample nutrients promote luxuriant shoot growth in indeterminate cultivars.

Based on these results, peanut culture is possible in NFT systems, but further work is needed to improve seed fill through increased photosynthate partitioning. Although the sphagnum substrate did not improve yields in this study, other types of substrates should be tested with various cultivars and environmental conditions. The hydroponic culture system described is applicable to bioregenerative life support systems and is a valuable research tool, where easy access to and visual inspection of developing pods are desired.

Table 1. Components of nutrient solutions used for peanut culture.

Salt	Culture solution	Refill solution
	mM	
KNO_3	2.5	46
$Ca(NO_3)_2$	2.5	12
KH_2PO_4	0.5	10
$MgSO_4$	1.0	10
	μM	
$FeCl_3$-HEDTA	60.0	100
H_3BO_3	9.5	93
$MnCl_2$	7.4	96
$ZnSO_4$	1.0	12
$CuSO_4$	1.0	13
$(NH_4)_6Mo_7O_{24}$	1.6×10^{-1}	10×10^{-2}

Table 2. Yield and partitioning of dry mass in peanut grown in hydroponic culture, where Solution = pod development in nutrient solution, Sphagnum = pod development in sphagnum substrate, EB = 'Early Bunch', and PT = 'Pronto'.

		Dry mass ($g \cdot m^{-2}$)				
Substrate	Cultivar	Shoot	Root	Pod	Seed	Total
Solution	EB	2310 ± 73[z]	140 ± 7	147 ± 13	407 ± 3	3003 ± 80
	PT	1883 ± 383	117 ± 20	100 ± 13	270 ± 40	2410 ± 380
Sphagnum	EB	2573 ± 27	130 ± 27	130 ± 10	287 ± 93	3120 ± 133
	PT	1853 ± 287	133 ± 37	140 ± 7	450 ± 3	2627 ± 303

[z]Values represent means for two culture trays (four plants) ±SD.

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